

CHARACTERISTICS OF ZnS: Sm AND ZnS: Tm THIN FILM ELECTROLUMINESCENCE DEVICES WITH MgF₂ DIELECTRIC LAYERS

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ABSTRACT

This paper reports characteristics of ZnS: Sm and ZnS: Tm thin film electroluminescence devices with MgF₂ dielectric layers. The thin film insulator, active layer (ZnS: Sm or ZnS: Tm), and electrode (Al) are deposited by thermal evaporation method by using a vacuum coating unit. The thickness of thin film was measured by a quartz-crystal thickness monitor. When a driving voltage is applied to an Metal Insulator Semiconductor Insulator Metal (MISIM) structure (ZnS:Sm and ZnS:Tm thin film electroluminescent devices with MgF₂ insulating layer), the EL brightness initially increases slowly, and then at a much faster rate before attaining a saturation value beyond particular applied voltage. The threshold voltage (U_{th}) is slightly higher for ZnS: Sm as compared to that for ZnS: Tm. The EL brightness of ZnS: Tm is nearly five times higher as compared to that of ZnS: Sm. The threshold voltage increases with increasing frequency of applied voltage. The saturation value of EL brightness increases linearly with frequency of the applied voltage for both, the ZnS: Sm and ZnS: Tm thin film EL devices. The EL brightness is optimum for the activator concentration of nearly 1000 ppm.

KEYWORDS: A C Thin Film Electroluminescence Device (ACTFELD), Brightness-Voltage, Electroluminescence, Luminescence Emission and MISIM Structure

INTRODUCTION

The technology of thin-film electroluminescent displays (TFELDS) has advanced rapidly since 1980. Yellow-emitting ZnS: Mn TFELD is now commercially available in a variety of sizes and resolutions [1-5]. But the development of full color displays has been postponed for several years due to the poor luminescence and efficiency of blue emission. The overcoming of this problem needs more detailed investigations on materials, devices and electroluminescence mechanisms. Prior research in the area of high-field transport in ZnS phosphor has considered various approaches ranging from lucky-drift models [7], to Monte Carlo calculations using parabolic conduction bands [6], non parabolic conduction bands [7], and simulation based on a local pseudo potential calculation for the first two conduction bands [8].

The use of single parabolic conduction band model [9] is clearly inadequate, since electrons subjects to the high fields typical of ACTFEL operations readily gain sufficient energy to transfer to higher bands. A no parabolic conduction band model provides a somewhat better estimated of the energy distribution of the carriers in the phosphors layer [7] The present paper reports the characteristics of ZnS Tm thin film electroluminescent devices with MgF₂ dielectric layers.

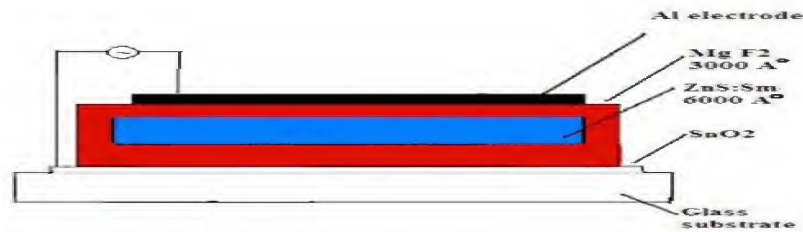


Figure 1: Structure of Thin Film Electroluminescent Device

METHOD

For present investigation ZnS: Sm and ZnS: Tm phosphors were prepared. Initially the vapors of SnCl_2 mixed with air were deposited on heated glass plate SnO_2 . This process was repeated until the desired results were obtained. The sheet resistance of conduction glass plate were nearly 50 Ohm cm. For deposition of insulator, active layer and electrode, the thin film of insulator MgF_2 active layer ZnS: Tm and, metal electrode (Al) were deposited by using thin film vacuum coating unit. Thickness of thin film was measured by using crystal thickness monitor. The brightness voltage characteristics of EL devices were measured by using photomultiplier tube. Figure 1 Shows the electroluminescent device.

RESULTS

Figure 2 shows the brightness (B) voltage-(U) characteristics of ZnS: Tm electroluminescent devices. It is seen that the EL starts beyond a particular voltage. With increasing value of the applied voltage, initially the brightness increases. Slowly and then at a fast rate. It is seen and finally it attains a saturation value. It is seen that the threshold voltage (U_{th}) is slightly higher for ZnS: Sm as compared to that of the EL brightness of ZnS: Tm is nearly five times higher as compared to that of ZnS: Sm. Figure 3 show the B-U characteristic of ZnS: Tm based EL devices for different frequencies of the applied voltage. It is seen that the threshold voltage increases with increasing frequency of the applied voltage and also similar results show for ZnS:Sm

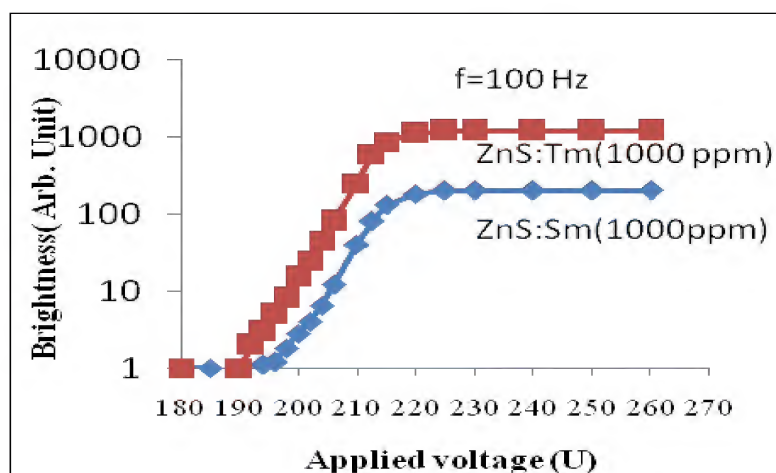


Figure 2: Brightness (B) Voltage (U) Characteristics of ZnS: Sm (1000 ppm) and ZnS: Tm (1000 ppm)

Figure 3 also shows that brightness increases with increasing of frequency. Figure 4 shows the dependence of EL brightness on the concentration of Sm and Tm in ZnS: Sm and ZnS: Tm phosphors and EL brightness is optimum for 1000ppm .

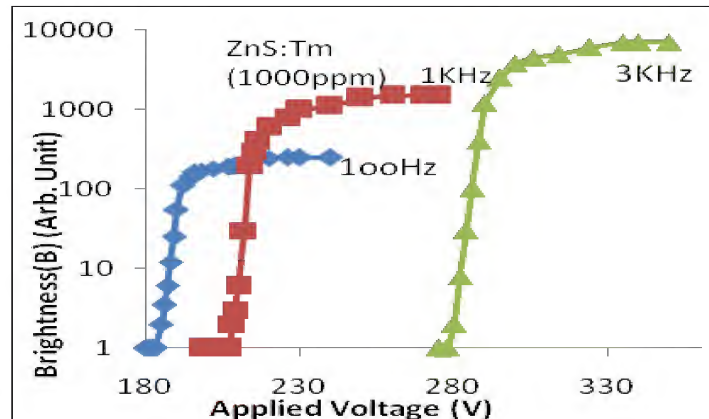


Figure 3: B-U Characteristics of ZnS: Tm (1000ppm) Based EL Device for Different Frequencies of the Applied Voltage

DISCUSSIONS

Energy band profile in the thin-film EL device with the aluminum electrode positively biased. The phosphor layer generally has high resistivity and is insulated from the electrode so that the device acts as an electrical capacitor. Higher for ZnS: Sm as compared to that ZnS: Tm.

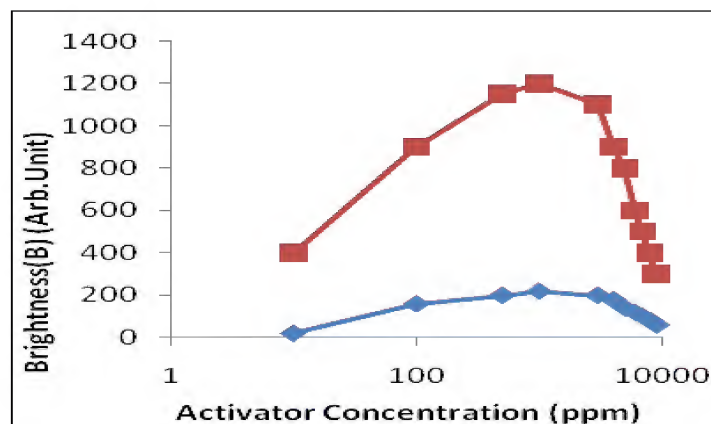


Figure 4: The Dependence of EL Brightness on the Concentration of ZnS: Sm and ZnS: Tm Phosphors

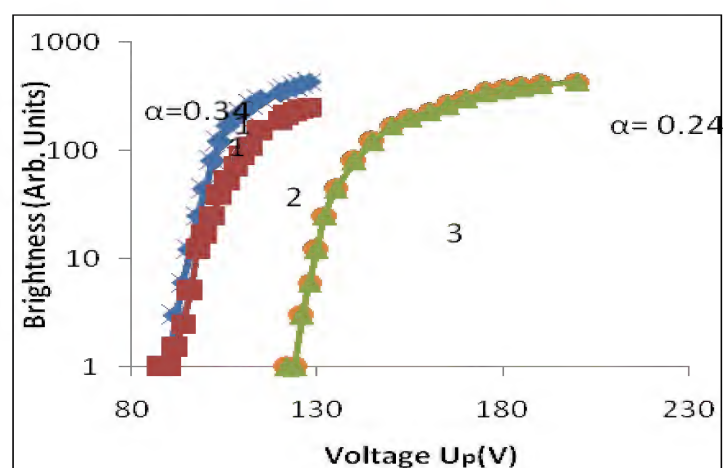


Figure 5: Brightness (B) – Voltage (U) Characteristics of an ac TFD with (1) $\alpha = 0.34$, (2) $\alpha = 0.24$ Same as in (1) but α Reduced by an External Capacitor; (3) Curve (2) Shifted to Make B Coincide at Low Brightness for Comparison Only

Electrons are injected from the interface states between phosphor and insulator layers by field emission. The injected electrons are accelerated and gain high kinetic energy to excite luminescent centers or the host lattice. Several modes for the excitation mechanisms of luminescent centers have been proposed and they are : direct impact excitation of luminescent centers via collision with the energetic electrons, the energy transfer from the ionized deep trap centers, and energy transfer from electron-hole pairs generated via energetic electron impact centers, the energy transfer from the ionized deep trap centre's to luminescent centers, and energy transfer from electron-hole pairs generated via energetic electron impact excitation of the host lattice to luminescent centers. The physical basis of electroluminescence mechanisms is not sufficiently clear as yet and this problem is a subject of scientific interest. The energetic electrons on the phosphor layer directly or indirectly induce the excited states of the luminescent centers. Phosphor layer directly or indirectly induce the excited states of the luminescent centers. Photons are emitted when radiative electrons transitions occur in the luminescent centre. The injected electrons travel through the phosphor layer and are finally retrapped at the opposite interface between phosphor and insulator layers. The same processes take place in the device with the aluminum electrode reversely biased. The mechanism of EL in thin Film electroluminescent can also be understood by following expression

$$B = \eta C_i \left[V - \frac{U_s(t)}{\alpha} \right] U_s(t) \quad (1)$$

When η is the conversion efficiency in lumen/watt $\alpha = \left[\frac{C_i}{C_i + C_s} \right]$ C_i is capacitance of two insulating layers of thin film, C_s is capacitance of the semiconductor layer, $U(t)$ is voltage developed across semiconductor in time t , and V is excitation of peak voltage. Above equation indicates that B should depend on: (i) η , (ii) $U(t)$, (iii) V , (iv) α and (v) C .

It has been found that different semiconductors used as active materials give different brightness. This fact indicates that brightness on efficiency η . Figure 2 shows the plot between brightness voltage U_p . It is seen that the EL emission takes place only after a particular value of the applied voltage. Figure 2 also indicates that the brightness B increases with the applied voltage and then it tends to attain a saturation value. The dependence of brightness on the voltage is indicated by equation (1). The saturation value of the brightness for higher value of the applied voltage may be due to the charges from the semiconductor to the insulator. Muller [10] has reported that for value of α less value of the threshold voltage is needed to cause the electroluminescence emission (Figure 5). Such fact is indicated by above equation, Muller [10] has also reported that low value of threshold voltage is needed for the EL device having higher of C_i . This may be understood in a following way.

Substituting $\alpha = \left[\frac{C_i}{C_i + C_s} \right]$, in above equation (1) may be expressed as

$$B = \eta C_i \left[V - U_s(t) \left(1 + \frac{C_i}{C_s} \right) \right] U_s(t) \quad (2)$$

It is evident from the above equation that for value of α , the value of the product $U_s(t) \left[1 + \frac{C_i}{C_s} \right]$ will be higher, therefore, higher value of U will be needed to cause the EL emission. On the other hand, for the higher value of α the value product will be low and consequently lower value of applied voltage will be needed to cause the EL emission. Figure 5 shows that for the higher value of α the threshold voltage is high. This results is also in accord with the proposed model.

It is evident from Figure 4 that the EL brightness is optimum for the activator concentration of nearly 1000 ppm. Initially, the number of luminescent centers increases with increasing concentration of the activator in the phosphor and,

therefore, the EL brightness increases with increasing concentration of the activator concentration in the phosphors. Thus, the EL brightness is optimum for a particular concentration of the activators in the phosphors.

CONCLUSIONS

The EL starts in ZnS: Sm and ZnS: Tm thin film electroluminescence devices beyond a particular voltage and also observed that the threshold voltage increases with increasing frequency of the applied voltage. The EL brightness increases with increasing of frequency, and brightness is optimum for 1000ppm.

REFERENCES

1. J F Wager and P. D. Keir Annu. Rev. Mater. Sci 27, (1997) 223
2. M. K. Jayaraj and C. P. G. Vallabhan J. Phys. D: Appl. Phys. **23** 1706- 1710. Printed in the UK (1990)
3. T. Weber et al. "Electroluminescence on the TCO corrosion of thin film modules", 25th EPVSEC, Valencia, p.3169. (2010)
4. D.C. Krupa and D. M. Mahoney. J. Appl.Phys.**43**, (2005) 2314
5. H.E. Gumlich: J. Lumines. **23**, (1981) 73
6. K. J. Brennan, Appl. Phys. 75(1994) 678.
7. M. Reigrotzki, et al, J.Appl. Phys.80 (1996) 5554.
8. T.D. Thompson. and O.W Allen, J. Phys. Conds. Sol. St. Phys. 20L (1978) 499.
9. M. Dur et al, J. Appl. Phys. 83 (1998) 3176.
10. G.O. Muller, Phys. Stat. Sol. (a) 81 (1984) 597.

